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Aburto-Corona, Jorge; Aragón-Vargas, Luis Fernando

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Investigación experimental o metaanalítica

REFINING MUSIC TEMPO FOR AN ERGOGENIC EFFECT ON STATIONARY CYCLING EXERCISE[1]

REFINANDO O TEMPO DA MÚSICA PARA UM EFEITO ERGOGÊNICO NO EXERCÍCIO DO CICLISMO ERGOMÊTRICO

Jorge Aburto-Corona (B,C,D,E) Jorge.aburto@uabc.edu.mx
Universidad Autónoma de Baja California, Tijuana, México, México
Luis Fernando Aragón-Vargas (B,C,D,E)
Centro de Investigación en Ciencias del Movimiento Humano, Universidad de Costa Rica, Costa Rica

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Abstract: Aburto-Corona, J. & Aragón-Vargas, L.F. (2017). Refining music tempo for an ergogenic effect on stationary cycling exercise. **PENSAR EN MOVIMIENTO: Revista de Ciencias del Ejercicio y la Salud, 15**(2), 1-12. The effect of music on exercise performance has been studied from many perspectives, but the results have not been as clear as expected, probably due to a lack of appropriate controls. The purpose of this study was to measure stationary cycling performance in a warm environment under carefully controlled conditions, modifying only the presence of music and its tempo. Ten physically active students, 24.5 ± 3.6 years (mean±SD) selected their favorite exercise music and performed a maximum cycling test. During subsequent visits to the laboratory, they pedaled at their preferred speed against a constant resistance (70% of maximum) in an environmentally controlled chamber (28.6±0.5 °C db and 65±3% rh) for 30 min, on three different days, without music (NM), medium tempo music (MT-120 bpm) or fast tempo music (FT-140 bpm), in random order. Perceived exertion (PE), heart rate (HR) and total work performed (W) were recorded. There was no significant difference among conditions for PE (4.47±1.52; 4.22±1.5; 3.83±2.06 a.u. for NM, MT and FT, respectively, p=.162) or HR (142.4±24.53; 142.6±24.37; 142.9±18.36 bpm for NM, MT and FT, respectively, p=.994), but W was different (43.4±19.02; 46.1±20.34; 47.1±20.97, kJ for NM, MT and FT, respectively, p=.009); post-hoc analysis showed that the W difference was only between FT and NM. Using individually selected preferred music in a carefully controlled environment, participants improved their spontaneous cycling performance only when the music had a fast tempo of 140 bpm.

Keywords: rhythm, endurance, beats, exercise performance.

Resumo: Aburto-Corona, J. & Aragón-Vargas, L.F. (2017). Refinando o tempo da música para um efeito ergogênico no exercício do ciclismo ergométrico. **PENSAR EN MOVIMIENTO: Revista de Ciencias del Ejercicio y la Salud, 15**(2), 1-12. O efeito da música durante o exercício tem sido estudado desde muitas perspectivas, mas os resultados não tem sido totalmente claros, provavelmente pela falta apropriada de controle na pesquisa. O propósito deste estudo foi medir o rendimento físico em uma bicicleta ergométrica em um ambiente quente, em condições cuidadosamente controladas, modificando apenas o tempo da música. Dez estudantes fisicamente ativos, 24.5±3.6 anos de idade (média ± desvio padrão), escolheram sua música favorita para fazer exercício e realizaram uma prova de máximo esforço na bicicleta. Durante as seguintes visitas ao laboratório, os participantes mantiveram uma cadência de sua preferência e uma resistência constante (70% da carga máxima) dentro de uma sala de clima controlado (28.6±0.5°C e 65±3%HR) por 30 minutos em três dias diferentes, sem música (NM), com música de ritmo moderado (MT-120bpm) ou música de ritmo rápido (FT-140bpm) em ordem aleatória. Foi registrado o esforço percebido (PE), a frequência cardíaca (HR) e o trabalho realizado (W). Não se encontrou diferença significativa entre condições PE (4.47±1.52; 4.22±1.5; 3.83±2.06u.a. para NM, MT e FT, respectivamente, p=.162) nem HR (142.4±24.53; 142.6±24.37; 142.9±18.36bpm para NM, MT e FT, respectivamente, p=.994). Porém, sim foram encontradas diferenças em W (43.4±19.02; 46.1±20.34; 47.1±20.97kJ para NM, MT e FT, respectivamente, p=.009); a análise post-hoc demonstrou que essas diferenças em W eram entre FT e NM. Ao utilizar música que cada pessoa gosta de ouvir enquanto se exercita em um ambiente cuidadosamente controlado, os participantes melhoraram o rendimento físico somente com ritmo rápido de 140bpm.

Palavras-chave: Ritmo, resistência, beats, rendimento físico.

Music, the art of combining sounds in harmony to elicit an aesthetic experience in listeners, is also a motivational stimulus for the human body (Harmon & Kravitz, 2007; Yanguas, 2006). According to several studies, this stimulus facilitates exercise, reducing fatigue, increasing intensity and improving efficiency while increasing emotional excitement, promoting relaxation, and improving coordination (Aragón-Vargas & Marín-Hernández, 2002; Elliott, Carr & Orme, 2005; Karageorghis et al., 2013; Szabo, Small & Leigth, 1999).

Previous studies have looked at the effects of music on physical performance; for example, muscular endurance, exercise intensity and pedaling cadence (Crust & Clough, 2006; Karageorghis, Jones & Low, 2006), motor abilities (Kravitz, 1994), power (Atan, 2013; Jarraya et al., 2012) and aerobic endurance (Ghaderi, Rahimi & Azarbayjani, 2009). Different theories have been proposed to explain the positive results, including the liberation of dopamine while listening to music (Menon & Levitin, 2005), or a distracting or dissociation effect (Waterhouse, Hudson, & Edwards, 2010), sometimes attributed to the unconscious synchronization between music and pacing of repetitive movements, or the proposed emergence of an intrinsic speed which enables individuals to exercise at higher intensities without paying attention to discomfort or fatigue (Crust & Clough, 2006; Karageorghis et al., 2006a; Waterhouse et al., 2010).

Music is, however, a very complex subjective experience, where many elements such as melody, harmony, rhythm, sound intensity, and lyrics play important roles. Individual preferences add an extra level of complexity (unpublished observations). To better understand the interaction of music and exercise, it would seem desirable to use a protocol where only one music element is manipulated at a time, while the rest are held constant; otherwise, it would be impossible to understand what variable is responsible for any effect found. We have selected tempo, one of the basic elements of rhythm. Rhythm is the expression of music time, associated with psychological time and chronological time. Tempo refers to the speed of music performance, commonly measured in beats per minute (bpm). Because music tempo could be strongly associated with pedaling cadence (pacing) during sports of a repetitive nature such as cycling, running, and swimming, it is a key element in the study of music and sports performance (Waterhouse et al., 2010).

Published studies have looked at fatigue, endurance, and recovery as dependent variables (Atan, 2013; Ghaderi et al., 2009), but also at exercise intensity or total work performed while exercising ad libitum to music (Aburto & Aragón-Vargas, 2013). Total work (and hence total calories burned) in a limited time are of particular interest to the fitness industry; total work is also expected to be particularly sensitive to the proposed association between tempo and pacing.

Therefore, the purpose of this study was to compare total work performed by young adults under carefully controlled conditions, during 30 minutes of self-selected exercise intensity cycling (submaximum, spontaneous intensity), while not listening to music, or while listening to individually-selected (preferred) music played at moderate or fast tempo. We chose to focus on spontaneous exercise on stationary bicycles in a warm environment, a typical health club scenario in the tropics.

METHODS

Participants. Ten apparently healthy, physically active college students (4 males and 6 females) volunteered to participate in this study. Their mean age, weight, and height are shown in Table 1. They signed an informed consent prior to participation, according to the policies of the University of Costa Rica Ethics and Science Committee. All subjects were occasional or non-cyclists, pedaling less than 15 km per week.

Procedures. Each participant visited the laboratory on five different occasions with a minimum of two days of rest between sessions. The first was a familiarization session, used to complete basic information and a physical activity readiness questionnaire (Rodríguez, 1994). Each individual was instructed to exercise comfortably on a cycle ergometer (Lode®, model Sport Excalibur, Groningen, Netherlands) for 30 minutes while listening to the music repertoire. The exercise equipment was adjusted to the subject's preferences, the settings were recorded, and the Brunel Music Rating Inventory-2 (Karageorghis, Priest, Terry, Chatzisarantis & Lane, 2006) was completed for each music track from a collection of 17 popular electronic music tracks commonly used for teaching aerobics or Spinning® classes. The average score of the music used was 5.7 ± 0.8 a.u., which on a scale from 0 to 7 could be rated as good. A preferred set of at least 10 music tracks, all originally recorded at 130 bpm, was produced from the results of these ratings for each individual. Virtual DJ software v.7.0.5—free version (Atomix Productions, California, USA) was then used to modify each set to play at the desired tempo, without modifying music pitch.

Session two was used to perform a maximum heart rate test using an adapted cycle ergometer protocol (MacDougall, Wenger & Green, 1991). Briefly, heart rate was monitored with a wireless monitor (Polar®, model FT4, Kempele, Finland) while each participant pedaled at 90 rpm, increasing the workload (resistance) every two minutes to the point of fatigue. Maximum resistance and heart rate were recorded.

Sessions three to five were the exercise performance trials: no music (NM), moderate tempo (MT, 120 bpm) or fast tempo (FT, 140 bpm), according to previous recommendations (Karageorghis et al., 2011; Karageorghis, Jones & Stuart, 2007; Karageorghis et al., 2006). All individuals performed all trials in a repeated-measures design; the order of trials was randomized. Upon arrival in the laboratory, participants lied down comfortably on their backs for five minutes listening to the music condition for that trial, while resting heart rate was measured. After a five-minute warmup on the cycle ergometer at 100 W, each participant was instructed to exercise submaximally at a self-selected intensity that he or she could maintain for 30 minutes. Resistance was set at 70% of each individual's maximum resistance obtained from session two, using the Lode® Ergometry Manager software. All trials were performed in a controlled climate chamber at 28.6 ± 0.5 °C dry bulb and 65 ± 3% relative humidity (Chen, Liu & Chen, 2015). Music tracks were played on a portable radio-CD player (Sony®, model CFD-RG880CP, New York, USA) at 75 ± 2 dB, as monitored with a sound level meter (Radio Shack®, model 33-2055, Texas, USA) placed on a tripod at the same height and distance from each participant's ears as the radio-CD player. Heart rate (HR), perceived exertion from 0 to 10 (PE, Borg, 1982), and work performed on the cycle ergometer (W) were recorded at the 10, 20, and 30-minute time points. Pedaling cadence (C) was recorded at the end of every minute for the duration of the exercise test and an average was calculated for the first, second, and third 10-min periods. At the end of each trial, cycle ergometer resistance was reduced and subjects were instructed to lower their pedaling cadence for five minutes, as a cool-down.

Therefore, selected tracks, music pitch, and ergometer resistance and geometry were all held constant over exercise trials for each individual; sound intensity, environmental conditions, and instructions were the same for all individuals and all trials. There was no feedback during exercise: participants did not have knowledge of elapsed time, pedaling cadence, heart rate, total work performed or distance covered. They were not informed about the actual study objectives until the end of the last session; originally, they were told that performance using different sports drinks was under study, and were given approximately 50 mL of an artificially flavored drink (same volume and same drink every time) before each trial.

Statistical analysis. Descriptive statistics (mean and standard deviation) were calculated for age, body mass and height, and actual maximum heart rate, in order to characterize the participants. All variables were checked for normality (Table 1).

Possible differences in resting heart rates among trials were analyzed with a one-way, repeated-measures analysis of variance. A two-way analysis of variance with repeated measures on both music trial and measurement time (3 x 3) was performed for each dependent variable:

heart rate, perceived exertion, work, and pedaling cadence. Post-hoc analyses were performed using a Bonferroni adjustment for multiple comparisons. Finally, several two-sample F-tests were used to make pedaling cadence minute-to-minute variance comparisons: NM vs. MT, NM vs. FT, MT vs. FT, and NM vs. the two music conditions combined.

RESULTS

Table 1 shows the general characteristics of the participants and results from the preliminary tests. There were no significant differences in resting heart rate (65.8 ± 12.6, 64.6 ± 12.6, and 68.4 ± 13 bpm; $F = 0.233$; $p = 0.794$) for the NM, MT and FT trials, respectively.

For perceived exertion (Figure 1a), there was not a significant interaction between trial and time ($F = 0.978$; $p = 0.432$). PE was not different among trials (4.5 ± 1.5, 4.2 ± 1.5, 3.8 ± 2.1, for NM, MT, and FT; $F = 2.018$; $p = 0.162$), but it increased significantly over time ($F = 23.274$; $p = 0.001$). Heart rate (Figure 1b) showed no interaction between trial and time ($F = 0.635$; $p = 0.641$). There was no significant difference in HR among trials (142.4 ± 24.5, 142.6 ± 24.4, 142.9 ± 18.4, for NM, MT, and FT; $F = 0.005$; $p = 0.995$), but HR increased significantly over time ($F = 27.320$; $p = 0.001$).

Table 1

Reference values

Characteristics	Males (4)	Females (6)	Total (10)
Age	21.5 ± 2.6	24.3 ± 3.7	23.2 ± 3.5
Height (cm)	186.2 ± 12.8	162.6 ± 1	172 ± 16.3
Weight (kg)	79.3 ± 12.9	60.5 ± 29.4	68.9 ± 27.5
HRmax (bpm)	189.8 ± 6.3	185. 2 ± 8.2	187 ± 8.1
Powermax (W)	148.4 ± 83.0	81.7 ± 37.5	108.4 ± 65.3
Rtrials (N*m)	11.0 ± 6.2	6.1 ± 2.8	8.1 ± 4.9

Source: the authors.

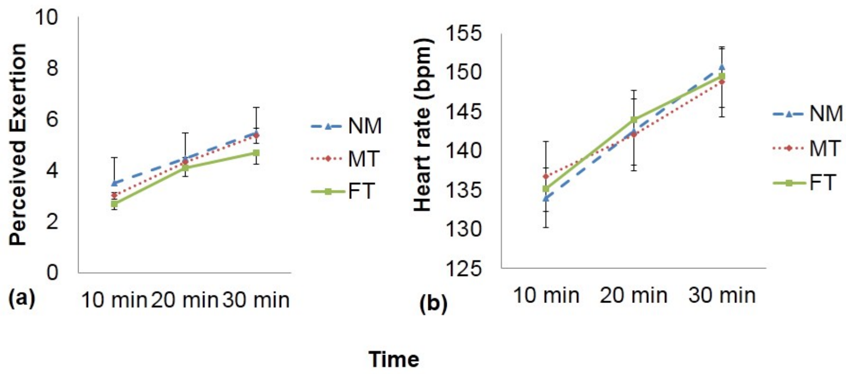

Figure 1
Physiological responses by trial and time
a) Perceived exertion. b) Heart rate. Points are mean values, bars represent the S.E.M. (*) p=0.001; (+) p=0.002
Source: the authors.

Figure 2 shows the work performed during each 10-min period. There was no significant interaction between trial and time (F = 0.555; p = 0.697) and no difference among periods (F = 1.351; p = 0.284), but total work was different among trials (F = 6.103; p = 0.009). Post-hoc analysis showed that FT (141.2 ± 20.5 kJ) was greater than NM (130.3 ± 18.54 kJ, p = 0.036), but not different from MT (138.3 ± 19.7 kJ; p = 0.100). MT was not different from NM, either (p = 0.085).

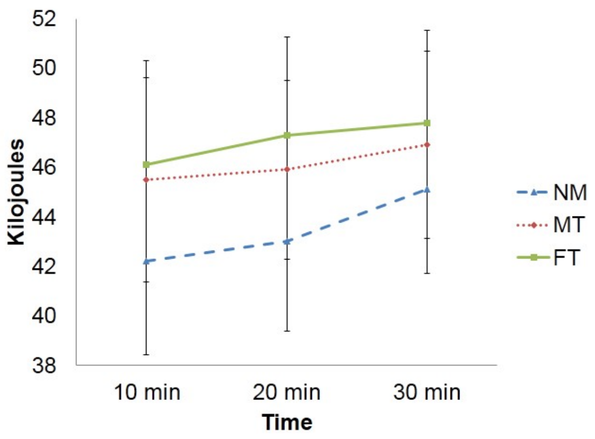

Figure 2.
Work performed by trial and time
Points are mean values, bars represent the S.E.M.
Source: the authors.

Pedaling cadence is presented in Figures 3a and 3b. There was no significant interaction between trial and time (F = 2.530; p=.057). Pedaling cadence was higher during the third period (98.6 ± 17.3 rpm) than the first (93.1 ± 15.7 rpm; p = 0.026), but the second period was not different from either (96.1 ± 16.8 rpm; p > 0.05). There was also a significant trial effect (Figure 3b): pedaling cadence was higher during FT (98.5 ± 15.5 rpm) than NM (92.8 ± 16.6 rpm; p = 0.021); MT (96.7 ± 17.6 rpm) was not different from the other trials (p > 0.05).

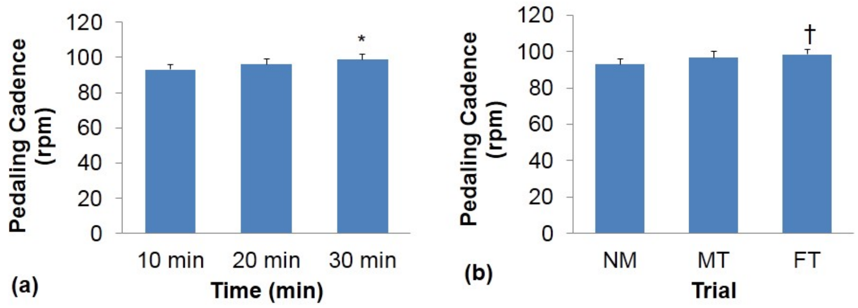

Figure 3.
Pedaling cadence
(*) Average from minutes 21 to 30 > average for minutes 1 to 10, p= 0.026. (†) FT > NM, p= 0.021. Mean plus S.E.M.
Source: the authors.

Minute-to-minute pedaling cadence variances were not different between NM (277.1 rpm2) and MT (310.0 rpm2, p = 0.33). FT (238.8rpm2) was not different from NM, (p = 0.20), but it was significantly lower than MT (p = 0.02). Pedaling cadence variance for the two music conditions combined (274.7rpm2) was not different for the no music condition (p = 0.92).

DISCUSSION

This study compared total work performed during 30 minutes of self-selected intensity cycling exercise under three music conditions. The main result was a higher amount of work performed while listening to preferred music at FT than when no music was played, while MT music was not different from the other two conditions.

Other studies have shown that when exercise intensity is higher than 70% HR_{max}, a 120 bpm tempo will result in better performance (Karageorghis et al., 2007; Karageorghis et. al., 2011). We failed to show an improvement at MT (120 bpm), even though self-selected exercise intensity for our subjects was 76.2 ± 11.0% HRmax. It is possible that due to the little experience of our subjects with stationary cycling, intra-subject variability may have been too large to detect significant differences with a 10-subject sample. A post-hoc power calculation showed that this sample size can detect a difference of 8 kJ with a power of 0.34. Our study, therefore, had the limitations of not using highly motivated indoor cyclists and having a moderate statistical power. It may also be the case that the discomfort resulting from exercising in a warm and humid environment may have blunted the ergogenic effect of the music.

There is an important additional limitation in this study, which must be considered before making any inferences from our results. Since all four dependent variables we analyzed are theoretically expected to be intercorrelated (see Table 2), a better statistical analysis would be a multivariate analysis of variance with repeated measures on both music trial and measurement time, including heart rate, perceived exertion, work, and cadence as dependent variables. Nevertheless, the sample size was not large enough to allow analysis of the trial X time X dependent variable interaction (residual degrees of freedom were insufficient). We found a multivariate, significant effect of trial (Wilk's Lambda = 0.057, p = 0.018) and measurement time (Lambda = 0.026, p = 0.004) on at least one of the dependent variables.

Table 2

Correlation matrix for the dependent variables

	Heart rate	Perc. exertion	Work	Cadence
Heart rate	1			
Perc. exertion	0.64[a]	1		
Work	-0.04	0.32	1	
Cadence	0.80[b]	0.35	-0.42	1

(a) $p = 0.042$ (b) $p = 0.006$.

Source: the authors.

In the present study, participants performed more work during the FT trial than when exercising without music (Figure 2), despite having similar ratings of perceived exertion and almost identical heart rates (figures 1a and 1b, respectively); this suggests a higher efficiency while listening to music at the higher tempo (Szabo et al., 1999), and it does not support a motivation or distraction effect which would have enabled the participants to sustain a higher exercise intensity in spite of fatigue or discomfort, two theoretical benefits of listening to music during exercise (Karageorghis et al., 2007). Fatigue was certainly not an issue in the present study, since more work was performed during the last 10 minutes of the 30-minute test than during the first 10-minute period. Unfortunately, we are unable to confirm the higher efficiency hypothesis with the calculation of power/heart rate reserve recommended by Szabo et al. (1999): in our study, the values obtained were 0.95, 1.02, and 1.07 for NM, MT, and FT, respectively ($p > 0.05$).

We speculate there may be an optimization of pedaling cadence with fast tempo music. Our comparison of minute-to-minute pedaling cadence variance showed more regularity (less variance) for the FT condition than the MT condition, although there was no difference between NM and FT. This provides weak support for an optimization of pedaling cadence with the fast tempo music, what some authors have called an intrinsic speed (Crust & Clough, 2006; Karageorghis et al., 2006a; Waterhouse et al., 2010). Our data would be consistent with the presence of an intrinsic pedaling cadence in humans in the absence of music, which is disturbed by MT music and enhanced with FT music. We found no evidence for a motivation or distraction effect in our data.

Our participants did not make a maximum effort, nor were they supposed to do so. On the contrary, it is possible that the resistance used was too low, considering the fact that average pedaling cadence used by the participants was high (96.7 ± 16.6 RPM) but the average power output (as calculated a posteriori from total work done in 30 minutes divided by 1800 seconds) was rather low (75.9 ± 33.3 W). A higher resistance may have resulted in a higher spontaneous power output and a higher total work completed.

This study presents some important strengths. We used preferred music, selected for each participant with the help of a published instrument (Karageorghis et al., 2006b). In addition to the intuitive benefit of this choice, studies have shown non-preferred music to actually have a negative psychological effect during exercise (Craig, 2009; Namakura, Pereira, Papini, Nakamura & Kokubun, 2010; Nikbakhsh & Zafari, 2012). Some published studies do not report whether the music they used was motivating to their participants (Atan, 2013; Jarraya et al., 2012). We also used objectively defined tempi for the experiment: it is not uncommon for authors to state that they worked with slow, medium, or fast tempo, without reporting the actual beats per minute used (Lingham & Theorell, 2009; Schie, Stewart, Becker & Rogers, 2008).

The other strength was that most, if not all, relevant variables were carefully controlled. Studies on the effect of music on exercise performance are subject to many important confounders, variables which can have an impact on exercise performance such as music preference and sound intensity, ambient heat, or participant awareness of their performance (ongoing feedback). Our study design allowed for a strict control of the relevant factors: environmental heat stress, sound intensity, selected tracks, music pitch, ergometer resistance and geometry, and feedback. Participants were not necessarily blind to the music conditions as it was obvious when no music was played, but tempo differences between FT and MT were carefully disguised and therefore not easy to detect consciously.

In the study of the effects of music on exercise performance, the control of all relevant variables is complex. The same way that studying the effects of exercise on health requires defining the type, duration, intensity, frequency and total volume of an exercise program, together with a careful selection of health outcomes, the systematic study of music involves controlling sound intensity, rhythm, tempo, harmony, lyrics and individual preferences, as well as selecting the most important exercise performance dependent variables. We recommend that future studies should follow our design, addressing one variable at a time. A better understanding of the major music component variables should provide a much better understanding of the effect of music, as a whole, on exercise performance.

CONCLUSIONS

This study confirms that preferred music at 75 dB can have a positive effect on stationary cycling performance, even at a moderate, spontaneous pace, such as typically selected by fitness participants. The effect was only significant when the music was played at 140 bpm. Future experiments with the same study design but a larger sample size and a higher ergometer resistance may show a positive effect for tempo = 120 bpm, compared to no music, and maybe even a difference between 120 and 140 bpm.

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Author notes

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